# Ein kurzer Überblick über die Geschichte der Theoretischen Physik in Göttingen


Die Physik in Göttingen beginnt ungefähr mit der Universitätsgründung in der Mitte des 18. Jahrhunderts und ist durch Namen wie Abraham Gotthelf Kästner, Tobias Mayer, Johann Ch. P. Erxleben und besonders Georg Christoph Lichtenberg bekannt geworden. Der Schüler, Mitarbeiter und spätere Kollege von Gauss, Wilhelm Weber, zeichnete sich nicht nur als Physiker, sondern auch als freiheitlich denkender Bürger aus. Schon zu seiner Zeit, also etwa ab 1849 entsprachen die beiden ordentlichen Lehrstühle des Fachs Physik in Göttingen (Weber, Listing) in etwa der Aufteilung in experimentelle und theoretische (mathematische) Physik. Die Abteilung "mathematische Physik" des physikalischen Instiutes wurde durch so bekannte Physiker wie Woldemar Voigt (1850-1919, ab 1883 in Göttingen), Peter Debye (1884-1966, in Göttingen 1914-1920) und Max Born (1882-1970, in Göttingen 1921-1933) geleitet. Unter letzterem erfolgte 1922 die Umbenennung in "Institut für Theoretische Physik".

**Woldemar Voigt**

*BIBLIOGRAPHY*

I. Original Works. Voigt's publications include *Mineralogische Reisen durch das Herzogthum Weimar und Eisenach*, 2 vols. (Weimar, 1781–1785); *Petrographische Landkarte des Hochstifts Fulda* (Frankfurt, 1782); *Mineralogische Reise von Weimar über den Thüringer Wald und Meiningen bis Hanau* (Leipzig, 1787); *Mineralogische und bergmännische Abhandlungen*, 3 vols. (Leipzig, 1789–1791); *Praktische Gebirgskunde* (Weimar, 1792); *Kleine mineralogische Schriften* (Weimar, 1799); *Mineralogische Reise nach den Braunkohlenwerken und Basalten in Hessen wie auch nach den Schieferkohlenwerken des Unterharzes* (Weimar, 1802); and *Geschichte des Ilmenauischen Bergbaues* (Sondershausen–Nordhausen, 1821).

II. Secondary Literature. There is no full-length biography, but Voigt is often mentioned in biographies of Werner and Goethe, and in works on the controversy over Neptunism—for instance, Walther Herrmann, *Goethe und Trebra*, which is Freiberger Forschungshefte, ser. D., no. 9 (Berlin, 1955), 36, 48–52, 62–64; and Otfried Wagenbreth, *Abraham Gottlob Werner und der Höhepunkt des Neptunistenstreits um 1790*, which is Freiberger Forschungshefte, ser. D, no. 11 (Berlin, 1955), see 183–241. A short biography is Carl Schiffner, *Aus dem Leben alter Freiberger Bergstudenten*, I (Freiberg, 1935), 16–17.

Hans Baumgärtel

**VOIGT, WOLDEMAR** (*b.* Leipzig, Germany, 2 September 1850; *d.* Göttingen, Germany, 13 December 1919), *physics.*

Voigt graduated from the Nikolaischule at Leipzig in 1868. He then entered the University of Leipzig, but in 1870 his studies were interrupted by service in the Franco-Prussian War. He resumed his studies in 1871, this time at Königsberg. At first Voigt was undecided between a career in physics and a career in music, for the latter had always played a large role in his life: Felix Mendelssohn and Robert Schumann had been frequent visitors to his parents' house. His musical ear was highly trained: and while in the army he would often pass the time while marching by reciting, note for note, the complete orchestration of entire symphonic pieces. He finally decided on a career in physics, on the ground that, unlike music, in physics there is a reasonable mean, not simply highs and lows.

While at Königsberg, Voigt came under the influence of Franz Neumann, his deep respect and love for whom largely determined his career, in terms of subject matter, the style of his research, and the manner in which he presented his work to the physics community. His dissertation on the elastic constants of rock salt was completed in 1874. He then returned to Leipzig, where he taught at the the Nikolaischule, but in 1875 was called back to Königsberg as extraordinary professor of physics. In 1883 Voigt was appointed ordinary professor of theoretical physics at Göttingen, with the promise that he and Eduard Reike were to have a new physical institute (which was not ready until 1905). His chief research interests centered on the understanding of crystals, but near the turn of the century he became more and more concerned with the Zeeman effect and the electron theory.

Voigt's interest in crystals was closely related to Neumann's work. At Königsberg, Neumann had worked in both the physics department and the department of mineralogy, so it was quite natural that he should do extensive work on the optical properties of crystals. Neumann had developed a mechanical theory of light propagation that assumed that light oscillations had a mechanical-elastic nature. The oscillations were transmitted through an ether conceived of as an elastic solid. He had not restricted his activities in physics to theoretical work, however, and had initiated a great number of experimental studies; his students spent many hours in his laboratories studying the properties of crystals.

Voigt brought this tradition of theoretical and experimental work to Göttingen. Although for many years he was hampered by lack of adequate facilities, he not only pursued theoretical studies of the properties of crystals but also undertook a host of very delicate experimental investigations in which the physical properties of many crystalline substances were measured.

According to the theories of Poisson and Cauchy, which were based on special molecular assumptions, certain relationships must exist between the constants of a crystal regardless of its classification. Voigt determined the elastic constants for a wide variety of crystals and showed that the predicted relationships were not at all satisfied. While some felt that this work vindicated those who objected to forming special hypotheses about the nature of crystals, Voigt did not accept this point of view and in many of his publications indicated the direction that must be taken in amending the molecular hypothesis.

In 1887, in a paper on the Doppler effect in which he analyzed the differential equations for oscillations in an incompressible elastic medium, Voigt established a set of transformation equations that later became known as the Lorentz transformations.

Voigt's extensive theoretical and physical researches on the nature of crystals were summarized in *Magneto- und Elektro-Optik* (1908) and *Kristallphysik* (1910). These treatises reveal the elegance of his mathematical treatments and the great orderliness that his research had brought to the understanding of crystals. The elastic, thermal, electric, and magnetic properties of crystals were ordered in magnitudes of three types: scalar, vector, and tensor. In fact, it was Voigt who in 1898 had introduced the term "tensor" into the vocabulary of mathematical physics.

Even though Voigt devoted considerable time to his research and his students, and even though he acquired more administrative responsibility at Göttingen, he never gave up an active interest in music and musicology. He was recognized as an expert on Bach's vocal works and in 1911 published a book on Bach's church cantatas. Voigt often referred to the study of physics in musical terms. To him the region of science that represented the highest degree of orchestration and that possessed the utmost in rhythm and melody was crystal physics. It was altogether fitting that on 15 December 1919 his funeral bier was carried from his house to its final resting place to the strains of a Bach chorale.

*BIBLIOGRAPHY*

I. ORIGINAL WORKS. There is no comprehensive catalog of Voigt's more than 200 publications. Among his most significant works are "Allgemeine Formeln für die Bestimmung der Elasticitäts Constanten von Krystallen durch die Beobachtung der Biegung und Drillung von Prismen," in *Annalen der Physik*, **16** (1882), 273–310, 398–415; "Volumen und Winkeländerung krystallinischen Körper bei all-oder einseitigen Druck," *ibid.*, 416–426; "Theorie des Lichtes für vollkommen durchsichtige Media," *ibid.*, **19** (1883), 873–908; "Zur Theorie des Lichtes," *ibid.*, **20** (1883), 444–452; "Theorie der absorbirenden isotropen Medien insbesonder Theorie der optischen Eigenschaften der Metalle," *ibid.*, **23** (1884), 104–147; "Theorie der electromagnetischen Drehung der Polarisationsebene," *ibid.*, 493–511; "Zur Theorie des Lichtes für absorbirende isotrope Medien," *ibid.*, **31** (1887), 233–242; and "Zur Erklärung der elliptischen Polarisation bei Reflexion an durchsichtigen Medien," *ibid.*, **32** (1887), 526–528.

Also see "Ueber das Doppler'sche Princip," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1887), 44–51; "Theorie des Lichtes für bewegte Medien," in *Annalen der Physik*, **35** (1888), 370–396; 524–551; "Zur Theorie des Lichtes," *ibid.*, **43** (1891), 410–437; "Ueber einen einfachen Apparat zur Bestimmung der thermischen Dilation fester Körper, speciel der Krystalle," *ibid.*, 831–834; "Bestimmung der Elasticitätsconstanten einiger quasi-isotroper Metalle durch langsame Schwingungen von Stäben," *ibid.*, **48** (1893), 674–707; "Bestimmung der Constanten der thermische-Dilation und des thermische-Druckes für einige quasi-isotrope Metalle," *ibid.*, **49** (1893), 697–708; "Die specifischen Wärmen $c_p$ und $c_v$ einiger quasi-isotroper Metalle," *ibid.*, 709–718; "Beiträge zur molecularen Theorie der Piëzoelectricität," *ibid.*, **51** (1894), 638–660; "Ueber Medien ohne innere Kräfte und über eine durch sie gelieferte mechanische Deutung der Maxwell-Hertz'schen Gleichungen," *ibid.*, **52** (1894), 665–672; and "Beiträge zur geometrischen Darstellung der physikalischen Eigenschaften der Krystalle," *ibid.*, **63** (1897), 376–385.

Additional works are "Zur kinetischen Theorie idealer Flüssigkeiten," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1897), 19–47, 261–272; "Lässt sich die Pyroelectricität der Krystalle vollständig auf piëzoelectrische Wirkungen zuruckführen?" in *Annalen der Physik*, **66** (1898), 1030–1060; "Doppelbrechung von im Magnetfelde befindlichen Natriumdampf in der Richtung normal zu den Kraftlinien," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1898), 355–359; "Ueber das bei der sogenannten totalen Reflexion in des zweite Medium eindringende Licht," in *Annalen der Physik*, **67** (1899), 185–200; "Zur Theorie der magneto-optischen Erscheinungen," *ibid.*, 345–365; "Ueber die Proportionalität von Emissions- und Absorptionsvermögen," *ibid.*, 366–387; "Weiteres zur Theorie der Zeemaneffectes," *ibid.*, **68** (1899), 352–364; "Neuere Untersuchungen über die optischen Wirkungen eines Magnetfeldes," in *Physikalische Zeitschrift*, **1** (1899), 116–120, 128–131, 138–143; "Zur Festigkeitlehre," in *Annalen der Physik*, **4** (1901), 567–591; "Beiträge zur Elektronentheorie des Lichtes," *ibid.*, **6** (1901), 459–505; "Elektronenhypothese und Theorie des Magnetismus," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1901), 169–200; and "Ueber einige neuere Beobachtungen von magneto-optischen Wirkungen," in *Annalen der Physik*, **8** (1902), 872–889.

Further, see "Ueber das optische Verhalten von Kristallen der hemiëdrischen Gruppe des monokinen Systemes," in *Physikalische Zeitschrift*, **7** (1906), 267–269; "Betrachtungen über die komplizierteren Formen des Zeemaneffektes," in *Annalen der Physik*, **24** (1907), 193–224; "Beobachtungen über natürliche und magnetische Drehung der Polarisationsebene in Krystallen von K. Honda," in *Physikalische Zeitschrift*, **9** (1908), 585–590; *Magneto- und Elektro-Optik* (Leipzig, 1908); *Kristallphysik* (Leipzig–Berlin, 1910; 2nd ed., 1926); "Zur Theorie der komplizierteren Zeemaneffecte," in

*Annalen der Physik*, **36** (1911), 873–906; "Allgemeines über Emission und Absorption in zusammenhang mit der Frage der Intensitätsmessungen beim Zeeman-Effect," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1911), 71–97; "Ueber Emission und Absorption schichtenweise stetig inhomogener Körper," in *Annalen der Physik*, **39** (1912), 1381–1407; "Weiteres zur Polarisation des Rowland Gittern gebeugten Lichtes," in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen* (1912), 385–417, written with P. Collet; "Ueber die anormalen Zeeman-effekte der Wasserstofflinien," in *Annalen der Physik*, **40** (1913), 368–380; "Weiteres zum Ausbau der Koppelungstheorie der Zeeman-effekte," *ibid.*, **41** (1913), 403–440; "Ueber die Zeeman-effekte bei mehrfachen Serienlinien besonders auch bei dem O-Triplet $\lambda = 3947$," *ibid.*, **43** (1914), 1137–1164; and "Ueber sekundäre Wirkungen bei piëzoelektrischen Vorgängen, insbesondere im Falle der Drillung und Biegung eines Krieszylinders," *ibid.*, **48** (1915), 433–448.

II. SECONDARY LITERATURE. See E. T. Whittaker, *A History of the Theories of Aether and Electricity*, 2 vols. (New York, 1960), I, 333, 415; II, 33, 160, 238–239. Obituary notices are by H. L[amb?], in *Proceedings of the Royal Society*, **99A** (1921), xxix–xxx; and by C. Runge, in *Physikalische Zeitschrift*, **21** (1920), 81–82; and in *Nachrichten von der Königlichen Gesellschaft zu Göttingen: Geschäftliche Mitteilungen aus dem Jahre 1920* (Göttingen, 1920), 47–52.

STANLEY GOLDBERG

**VOIT, CARL VON** (*b.* Amberg, Bavaria, 31 October 1831; *d.* Munich, Germany, 31 January 1908), *physiology*.

Voit was the son of August Voit, a well-known architect. He entered medical school in Munich, in 1848, and completed his training there in 1854, after spending the year 1851 at Würzburg. In 1855 he studied chemistry in Göttingen with Wöhler, and the following year became an assistant to Theodor Bischoff at the Physiological Institute in Munich. In 1859 he became a lecturer at the University of Munich, and in 1863 he was named professor of physiology, a position he held for the rest of his career. During the next three decades Voit became the leader of the dominant school investigating metabolism. He acquired an authoritative position through the technical mastery with which he refined previously developed procedures, and by means of which he was able to resolve fundamental problems into which his predecessors had fallen.

When Voit returned to Munich in 1852, he attended Liebig's chemistry course, and was inspired by Liebig's writings on "animal chemistry" to investigate the "laws" of animal nutrition. For many years Voit was guided by Liebig's theory that the organized parts of the body are formed exclusively by nitrogenous "albuminoid" nutrient substances (plastic aliments), and that non-nitrogenous nutrients (respiratory aliments) are oxidized in the blood to produce animal heat. He also adhered to Liebig's belief that all mechanical work is produced by the "metamorphosis" of the nitrogenous tissue constituents. Liebig's contention that one could measure the amount of tissue metamorphosis by the formation of urea provided the research program to which Voit devoted much of his career. At the time Voit entered this field, Jean-Baptiste Boussingault, Friedrich Bidder and Carl Schmidt, and Bischoff had already carried out extensive comparative measurements of the intake and output of the elements (carbon, hydrogen, oxygen, and nitrogen) constituting the bulk of the food, excretions, and respiratory gases of animals. Their results had created several theoretical and practical dilemmas. They realized that one should ideally measure the composition of the food and excrements simultaneously with the gaseous exchanges, but the differing experimental conditions appropriate respectively to the collection of the excrements and to that of the respiratory gases had prevented this. In 1852 Bischoff encountered another serious setback. Using a simple and reliable new method developed by Liebig for measuring urea, Bischoff found that large portions of the dietary nitrogen were unaccounted for in the urine; this unexplained nitrogen "deficit" seemed to preclude direct measurements of the turnover of nitrogenous tissue constituents.

When he became Bischoff's assistant, Voit continued Bischoff's feeding experiments on dogs. Taking care to assure that the nitrogen content of the meat that was fed to the dogs was uniform, and to collect the feces and urine without losses, Voit found that the nitrogen absorbed in the meat was always nearly equal to that in the urea, or could be accounted for by the weight changes in the animal. This outcome reassured Voit that under rigorously controlled conditions one could rely on the quantity of urea excreted as a measure of nitrogenous metabolism.

Encouraged by this success, Voit carried out extensive further investigations with Bischoff, determining the quantities of urea formed by a dog under various dietary conditions. Between 1857 and 1860 they tried pure meat diets, in which they systematically increased and decreased the daily quantities, and combinations of meat with varying